SPIN POLARIZATION OF HYPERONS IN THE HADRON-HADRON INCLUSIVE COLLISIONS

KEN-ICHI KUBO

School of Science, Tokyo Metropolitan University,
1-1 Minami-osawa, Hachioji, Tokyo 192-0397, Japan
E-mail:kubo@comp.metro-u.ac.jp

KATSUHIKO SUZUKI

Division of Liberal Arts, Numazu College of Technology,
3600 Ooka, Numazu, Shizuoka 410-8501, Japan

We discuss interplay of the scalar and vector diquarks which decide the characteristics of the spin polarization as functions of p_T and x_F in the wide kinematical range. We demonstrate a significant effect of quark masses on the pair-creation probabilities from vacuum in $pp \to \Sigma^- X$ and $\gamma p \to \Lambda X$ collisions, and also a remarkable correction induced by the diquark form factor in $\Sigma^- p \to \Lambda X$ collision.

1. Introduction; the global model

The high energy hadron-hadron collisions produce various hyperons, in which large spin polarizations perpendicular to a production plane are observed at high Feynman-x (x_F) and low transverse momentum p_T. For these collisions, we have proposed a global model on the basis of quark rearrangements concept[1]. In order to produce a final state hyperon at high x_F, we consider possible rearrangement processes allowed by the SU(6) symmetry, where valence quarks (diquarks) from the injectile combine with sea quarks created from vacuum. Evaluation of rearrangement amplitudes in terms of relativistic quarks and diquarks with the confinement force in fact provides the spin asymmetry. We assume that the polarization is principally brought about by the rearrangement mechanism, while all other processes such as the standard fragmentation, which usually comes from showers of partons rather than the valence quark of the injectile and thus negligible at high x_F, are spin-independent. If this concept would work for the various hadron productions, we can consistently apply it to evaluations of the spin observables by any injectile collisions.

We have applied the model to the various data existing and obtained a general success for the spin observables induced by the strong[1,2], electromagnetic[3,4,5] and weak[4,5] interactions, and also for the several so-called puzzling cases[6]. In the presentation, from our recent works, we have concerned about the two indications; the quark masses mechanisms (QMM) and the form factor dynamics (FFD), for the polarizations in $pp \to \Sigma^- X$, $\gamma p \to \Lambda X$ and $\Sigma^- p \to \Lambda X$ collisions.

2. The quark masses mechanisms

· <u>The spin polarization of $pp \to \Sigma^- X$ at 400 GeV/c</u>

Our global model calculation is compared to the data producing Σ^- in Fig.1 and it predicts a large negative polarization contrary to the positive values in observation. In this process, a d-valence quark from the injectile p combines with scalar $(ds)^0$ or vector $(ds)^1$ diquarks created from vacuum. The discrepancy arises from too much enhancement of the vector diquark contribution. For resolving the problem, we shall take into account the mass dependence of probabilities to create the sea diquarks. Within our framework, sea quarks are assumed to be produced non-perturbatively by the string breaking in the hadronization process. So far in the previous works[1,3], we took the same production rate for the creation of the all kinds of quarks. However, it has been suggested that probabilities of the pair-creation certainly depend on their masses[7]. Indeed, a simple calculation yields a rate of the pair-creation as, $C^i_{QMM} = \exp[-\pi(m_i^2 + k_T^2)/\kappa]$, where m, k_T, κ are the constituent mass of quark(s) i, transverse momentum, and the string tension 1GeV/fm, respectively. For the diquark creation we concern, the diquark mass depends on its internal spin state, and the scalar diquark mass m_S is less than the vector one m_V. This is due to a property of the interaction acting between the two quarks; attractive for $S = 0$, while repulsive for $S = 1$. With $m_S = 0.8$GeV and $m_V = 1$GeV, the spin polarization in our model[1] is then corrected into the form

$$P(x_F, p_T) = \frac{R_S\langle C^S_{QMM}\sigma^S_{dep}\rangle + R_V\langle C^V_{QMM}\sigma^V_{dep}\rangle}{\langle C^S_{QMM}\sigma^S_{ind}\rangle + \langle C^V_{QMM}\sigma^V_{ind}\rangle} \tag{1}$$

The correction is expected to reduce the vector diquark contribution dramatically and in fact we have found a significant effect for improvement of the calculation as we can see in Fig.1.

· <u>The spin polarization of $\gamma p \to \Lambda X$ at $\nu = 16$GeV</u>

Further application of QMM has been made for the spin polarization of

$\gamma p \to \Lambda X$ extracted from HERMES data. In this case, u, d, s quarks from γ contribute to the Λ production through the rearrangements $u + (ds)^{0,1}$, $d + (us)^{0,1}$, and $s + (ud)^0$. Our original model predicts the dashed curve in Fig.2, which is too big with negative-sign contrary to positive-sign in the observation. Then we include QMM and got the solid curve which now well reproduces the observation with $m^S_{ud} = 0.6\text{GeV}$ and $m^V_{us} = m^S_{us} = 1\text{GeV}$.

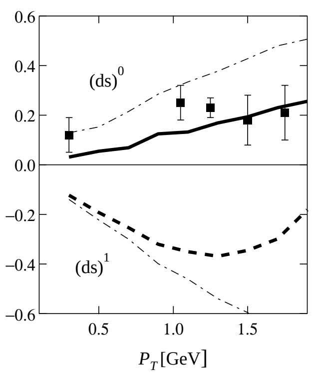

Figure 1. Polarization of $pp \to \Sigma^- X$. The dashed and solid curves show the results without and with QMM.

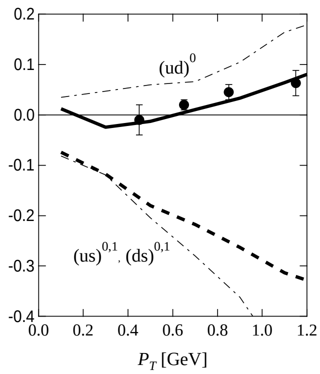

Figure 2. Polarization of $\gamma p \to \Lambda X$. Notations are the same as those of Fig.1.

3. The form factor dynamics: $\Sigma^- p \to \Lambda X$ at 340 GeV/c

The full observation has been reported for the polarization of $\Sigma^- p \to \Lambda X$ in a wide kinematical range. The most notable point in the observation is change of sign of its p_T distribution around $x_F = 0.4$, of which shape may not be reproduced by any theoretical calculation using the existing models. Our straight forward calculation with the rearrangements $(ds)^0 + u$ and $(ds)^1 + u$ predicts only a monotonically increasing result in Fig.3a due to the dominance of the positive $(ds)^1$ contribution.

Then, we consider here property of the diquark wave functions in the configuration space, which should be different between the scalar $(ds)^0$ and vector $(ds)^1$ diquarks due to attractive or repulsive nature of the color magnetic force. This interaction may induce a difference of sizes of diquarks, r_S and r_V, and indeed such a difference is observed within the rigorous three-body calculation of the baryon structure[8].

For taking it into account, it may be reasonable to introduce a form factor for the quark-diquark interaction vertex. We take a form $C^{S,V}_{FFD} = \exp(-r^2_{S,V} p^2_T)$ to be multiplied to each cross section, similarly to eq. (1),

with $r_S = 0.5$fm and $r_V = 0.7$fm. We can see in Fig.3b that the FFD correction reduces the monotonical increase of the vector component previously seen. Therefore the new calculation with FFD provides a remarkable change and improves the calculation

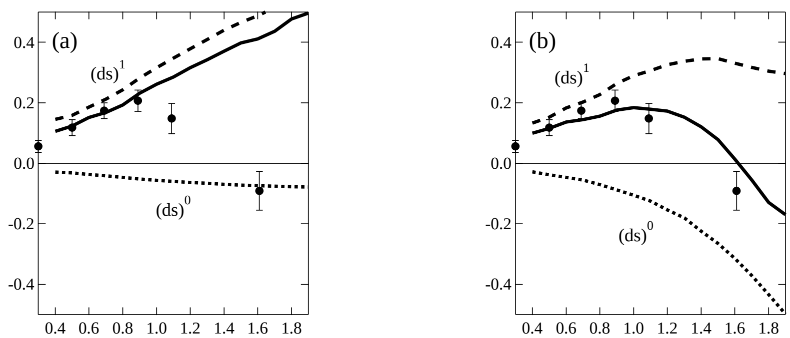

Figure 3. Polarization of $\Sigma^- p \to \Lambda X$ without FFD (left) with FFD (right).

4. Conclusion

We discussed the inclusive hyperon productions and the spin polarizations. We concentrated on the role of interplay of the scalar and vector diquarks. It has been found that, in general, the vector component shows a too much predominance. Then we have considered the quark masses mechanisms which provide a significant effect to improve the calculations by reflecting difference in masses of diquarks created from vacuum. The form factor dynamics due to the diquark internal structure has been also found to provide a remarkable change of the calculation.

References

1. Y. Yamamoto, K.-I. Kubo and H. Toki, Prog. Theor. Phys. **98** (1997) 95.
2. K. Suzuki et al., Mod. Phys. Lett. **A14** (1999) 1403.
3. K. Suzuki, N. Nakajima, H. Toki and K.-I. Kubo, proceedings of the 14th Intern. Spin Phys. Symp. (Osaka 2000), AIP Proc. **570** (2001) 499.
4. K.-I. Kubo, K. Suzuki and N. Nakajima, Proc. Symm. and Spin (Praha 2001), Czech. J. Phys. **52** (2002) C91.
5. K.-I. Kubo and K. Suzuki, proceedings of the 10th Intern. Conf. Nucl. Reaction Mechanisms (Varenna 2003), (2003) 559.
6. K.-I. Kubo, Y. Yamamoto and H. Toki, Prog. Theor. Phys. **101** (1999) 615.
7. See e. g., The Lund Model, Bo Andersson (Cambridge Univ. Press, 1998).
8. E. Hiyama et al., Prog. Theor. Phys. **112** (2004) 99.